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Research report

The effects of extended bedtimes on sleep duration and food desire in overweight young adults: A home-based intervention ☆

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ABSTRACT

Introduction: Sleep curtailment is an endemic behavior in modern society. Well-controlled laboratory studies have shown that sleep loss in young adults is associated with increased desire for high-calorie food and obesity risk. However, the relevance of these laboratory findings to real life is uncertain. We conducted a 3 week, within-participant, intervention study to assess the effects of extended bedtimes on sleep duration and food desire under real life conditions in individuals who are at risk for obesity. *Methods*: Ten overweight young adults reporting average habitual sleep duration of less than 6.5 h were studied in the home environment. Habitual bedtimes for 1-week (baseline) were followed by bedtimes extended to 8.5 h for 2-weeks (intervention). Participants were unaware of the intervention until after the baseline period. Participants received individualized behavioral counseling on sleep hygiene on the first day of the intervention period. Sleep duration was recorded by wrist actigraphy throughout the study. Participants rated their sleepiness, vigor and desire for various foods using visual analog scales at the end of baseline and intervention periods. *Results*: On average, participants obtained 1.6 h more sleep with extended bedtimes (5.6 vs 7.1; $P < 0.001$) and reported being less sleepy ($P = 0.004$) and more vigorous ($P = 0.034$). Additional sleep was associated with a 14% decrease in overall appetite ($P = 0.030$) and a 62% decrease in desire for sweet and salty foods ($P = 0.017$). Desire for fruits, vegetables and protein-rich nutrients was not affected by added sleep. *Conclusions*: Sleep duration can be successfully increased in real life settings and obtaining adequate sleep is associated with less desire for high calorie foods in overweight young adults who habitually curtail their sleep.

Introduction

Sleep curtailment has become an increasingly prevalent behavior in modern society. It is estimated that average sleep duration has decreased by 1.5–2 h in the past half century. Today, as many as one-third of American adults report obtaining less than 7 h of sleep. According to a recent survey by the National Sleep Foundation (Centers for Disease Control and Prevention, 2011), roughly one-third of Americans reported, "not getting enough sleep" by comparing the hours of sleep they say they need to the hours of sleep they are actually getting on workdays or weekdays. Overall, more than half of them agreed that "not getting enough sleep" affects their job performance, ability to carry out household duties, relationship with family or friends, and ability to perform everyday activities.

Substantial evidence from population studies suggests that young adults reporting short habitual sleep durations are at increased risk of developing obesity (McNeil, Doucet, & Chaput, 2013; Nielsen, Danielsen, & Sorensen, 2011; Patel & Hu, 2008). Well-controlled laboratory studies have demonstrated that sleep restriction in young adults is associated with alterations in appetite regulation, particularly with more desire for high calorie foods (Chaput, Klingenberg, & Sjodin, 2010; Greer, Goldstein, & Walker, 2013; Schmid, Hallschmid, Jauch-Chara, Born, & Schultes, 2008; Spiegel, Tasali, Penev, & Van Cauter, 2004), which may increase the risk for weight gain. However, the relevance of these laboratory findings to real life has not been studied. In other words, there has been no intervention study so far that has investigated whether sleep time can be improved in real-life settings and whether additional sleep has any beneficial effects in individuals who are at risk for obesity. This may be because it is commonly believed that increasing sleep duration may be difficult to achieve in real life where individuals have priorities and other responsibilities competing with sleep.

Therefore, we designed our study using a home-based intervention aimed at extending bedtimes and evaluated its effects on sleep duration and food desire in at-risk individuals, while they live in their

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usual environment. We hypothesized that sleep duration can be increased in real life settings with a behavioral intervention to extend bedtimes through individualized sleep hygiene counseling. We further hypothesized that additional sleep has beneficial effects on appetite and decreases cravings for weight-promoting, high calorie foods in overweight young adults who habitually curtail their sleep.

Methods

Design overview

The study was approved by the University of Chicago institutional review board. We conducted a within participant, intervention study under real life conditions, beginning with habitual bedtimes (baseline period; nights N01–N07) for 1 week immediately followed by extended bedtimes (intervention period; nights N08–N21) for 2 weeks. Participants were unaware of the intervention until after the habitual bedtime period to ensure that they did not modify their habitual sleep–wake behavior, and thus their habitual sleep patterns were effectively captured at baseline. Participants were told that the purpose of the study was to collect information on their sleep–wake patterns at home. They were also told that they may be asked to modify the timing of sleep, but not that this change would result in a sleep extension. The advertisements stated that the study involves completing questionnaires and wearing a wrist watch at home for 3 weeks. Participants received individualized behavioral counseling about sleep hygiene on the first day of the intervention period. We objectively monitored sleep–wake patterns by continuous wrist actigraphy during the entire 3-week study. Participants rated their sleepiness, vigor and desire for various food items at the end of the baseline and intervention periods.

Participants and setting

Overweight adults (age range: 21–40 years; body mass index range: 25.0–29.9 kg/m^2) reporting an average habitual sleep duration of <6.5 h were recruited through local advertisements. Exclusion criteria were insomnia, regular napping, shift work, extreme chronotype, travel across time-zones within the past 4 weeks, history of eating or psychiatric disorders, acute or chronic medical condition, alcohol abuse, smoking, pregnancy or childbirth (past year), any prescription medications, and current enrolment in diet or exercise programs. Eligibility was established by a structured survey and a brief interview. Eleven participants, who met the eligibility criteria, were enrolled. Wrist actigraphy recordings failed and were incomplete in one woman, who was excluded from the analysis. Data from the remaining 10 participants (five men, five women), who completed the study, are presented. Throughout the entire study, the participants followed their daily routine activities and slept in their usual home environment.

Intervention: extended bedtimes

During the first week of the study, participants were asked to continue their habitual bedtimes at home. On the first day of the intervention period, participants met with the study investigators in an office setting to receive individualized behavioral counseling on sleep hygiene through a structured interview. First, all social and environmental factors related to habitual sleep patterns were discussed in detail. Actigraphy data from baseline period was briefly reviewed. Next, individualized behavioral counseling on sleep hygiene was provided with the goal of accommodating the extended bedtimes in the participant's lifestyle in the best possible way. Participants also received counseling about potential modifiable factors and other barriers in their lifestyle that may prevent them from extending bedtime duration. As necessary, factors related to sleep partner, children, other family members and pets were considered and individual recommendations were provided to better implement extended bedtimes into the daily routine. At the end of the interview, participants were provided with individualized recommendations to follow at home for 2 weeks, aiming to extend bedtime duration to 8.5 h (with the intention to increase sleep duration to the healthier length of 7–8 h per night). Bedtimes and wake-up times were individually designed, taking into account personal schedules and priorities. At the end of the first week of the intervention period, the participants returned for a brief follow-up visit. Actigraphy data from the first week of the intervention period was reviewed and further counseling was provided, as needed.

Data collection

Participants were asked to wear a wrist activity monitor (Actiwatch 64, Mini-Mitter Respironics, Inc) on the nondominant arm throughout the study. This monitor detects participants' movement via accelerometers and has a built-in event marker. Participants were asked to press the event-marker button when they went to bed to sleep each night and when they got out of bed each morning. Participants also kept daily sleep logs to indicate the times when they went to bed and got out of bed. At the beginning of the study, participants completed the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) to assess overall sleep quality and Morningness–Eveningness questionnaire (Horne & Ostberg, 1976) to determine chronotypes.

At the end of each study period, participants completed validated visual analog scales of vigor (Monk, 1989) and appetite (Spiegel et al., 2004) in the morning before eating their breakfast. Sleepiness was determined from the response to the question "How sleepy do you feel?" on a 10-cm scale (with "very little" and "very much" as limits). Food desire was assessed by asking the participants to mark their ratings of how much they would enjoy eating various food items on a 10-cm scale (with "not at all" and "very much" as limits). Participants were asked to provide their ratings at the moment, without concern for calories, fat, or a healthy diet.

Data analysis and statistics

Sleep was automatically scored by Actiware Version 5 software (Respironics, Inc), an actigraphy-based sleep-scoring program using previously described and validated algorithms (Ancoli-Israel et al., 2003). Sleep duration was calculated as the sum of all epochs scored as sleep during the time in bed. Variability across nights in a participant's sleep duration was summarized using the coefficient of variation. Sleep data were averaged across nights in each participant for each study period. Sleep efficiency (reported as percentage) was defined as the total sleep time divided by the total time spent in bed multiplied by 100. Sleep latency was defined as the time in minutes before sleep onset following the bedtime. Comparisons between habitual bedtime and extended bedtime periods were performed using a two-sided paired t-test with a significance level of 0.05 (JMP 9.0.2, SAS Institute). Results are reported as mean ± SE.

Results

Participants had a mean age of 28.6 ± 1.7 years and mean body mass index of 28.0 ± 0.6 kg/m^2. Five had full-time and two had part-time jobs, two were working from home, and one was a student. The sample was comprised of three Caucasian, four African-American, one Asian and two Hispanic participants. At the beginning of the study, the average Pittsburgh Sleep Quality Index score was 5.1 ± 0.5. None of the subjects were extreme chronotypes as as-

Table 1
Effect of bedtime extension on actigraphy-based sleep characteristics.

Characteristic	Habitual bedtimes	Extended bedtimes	*P* value
Sleep duration (hour)	5.6 (0.1)	7.1 (0.1)	<0.001
Bedtime duration (hour)	6.4 (0.2)	8.2 (0.1)	<0.001
Sleep efficiency (%)	86.5 (1.4)	86.5 (1.3)	0.995
Sleep latency (minute)	8.2 (1.8)	10.6 (1.7)	0.282
Daytime activity (counts/minute)[a]	394 (25)	423 (24)	0.020

Data are mean (SE).
[a] Calculated as the average activity counts from the wrist actigraphy recordings during the periods when subjects were not in bed to sleep.

sessed by the Morningness–Eveningness questionnaire with an average score of 50.0 ± 1.8.

Overall, participants slept 1.6 h more with extended bedtimes as compared with habitual bedtimes (Table 1). Night-to-night variability in sleep duration was similar between study periods ($P = 0.33$) with a mean coefficient of variation of 13.6% (range: 6.1–25.5%) during habitual bedtimes and 11.1% (range: 6.7–21.4%) during extended bedtimes (Fig. 1A). Bedtime duration was increased by 1.8 (0.2) hours with the intervention (Table 1). On average, the participants went to bed ~1 h 15 min earlier with the intervention (hh:mm; 00:54 ± 00:17 during habitual bedtimes vs 23:38 ± 00:13 during extended bedtimes) and got up ~30 min later (hh:mm; 07:19 ± 00:23 during habitual bedtimes vs 07:52 ± 00:17 during extended bedtimes). Sleep efficiency and latency were similar during both study periods, confirming that the participants were habitually sleep deprived. The intervention resulted in increased sleep duration in all 10 participants (Fig. 1B). As expected, the magnitude of increase in sleep duration varied among participants (ranging from 37 min to 2 h 44 min) with an increase of at least 1 h in eight out of 10 participants. Sleep duration increased by an average of 1.4 ± 0.1 h on weekday nights and 1.9 ± 0.3 h on weekend nights (Fig. 1C). Sleep extension, relative to habitual sleep, was associated with a ~7% increase in average daytime activity (Table 1).

Participants reported being less sleepy ($P = 0.004$) and more vigorous ($P = 0.034$) with extended bedtimes relative to habitual bedtimes (Table 2). More sleep was associated with a 14% decrease in overall appetite ratings when all food categories were considered. Desire for sweet and salty foods was decreased by 62%, whereas desire for fruits, vegetables and protein-rich nutrients were not affected by additional sleep.

Discussion

We demonstrated that a 2-week home-based behavioral intervention to extend bedtimes results in increased sleep duration in

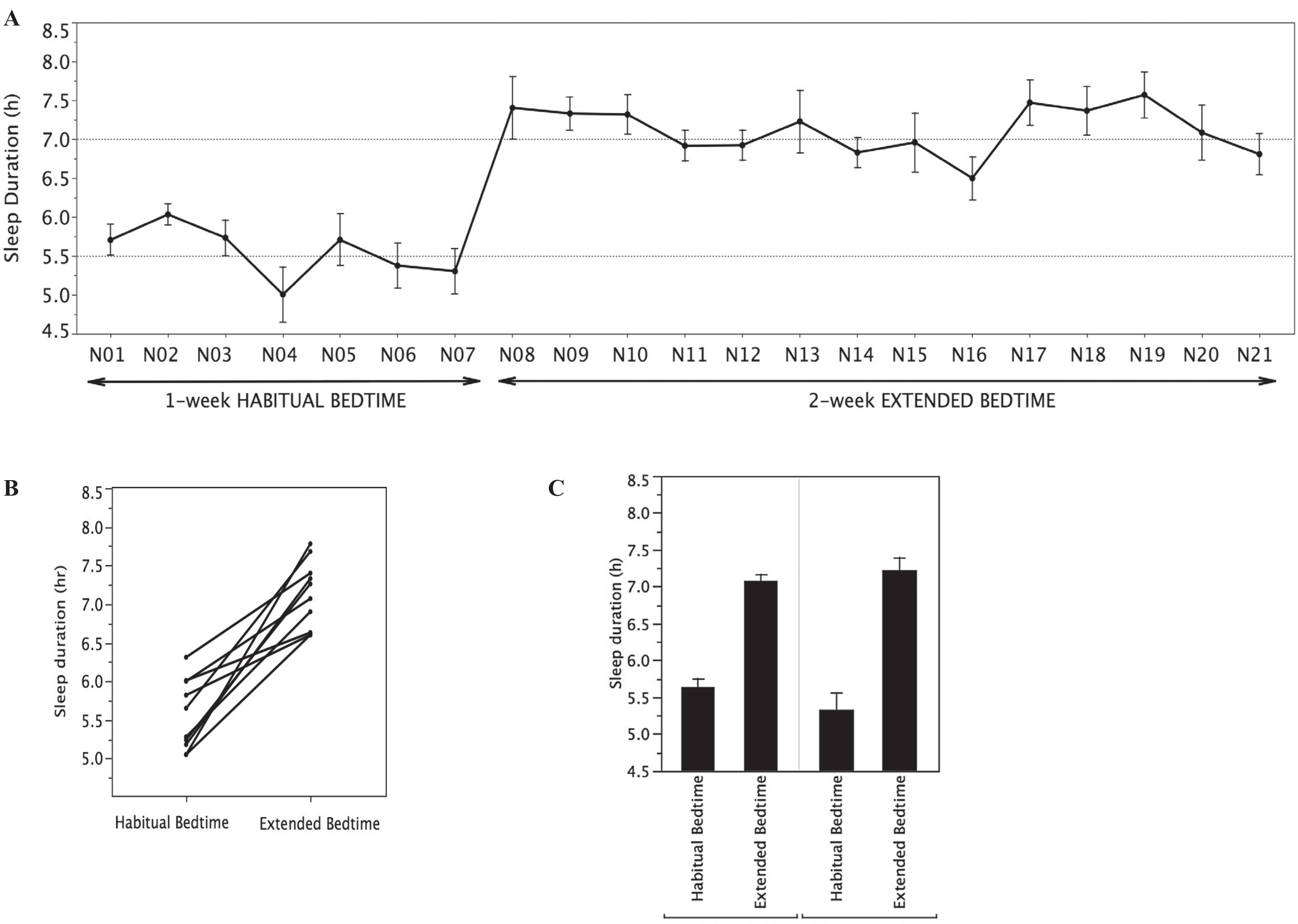

Fig. 1. Sleep duration during habitual bedtime and extended bedtime. (A) Mean (SE) night-by-night sleep duration during the habitual bedtime period (nights N01–N07) and extended bedtime period (nights N08–N21). (B) Individual changes in average sleep duration between habitual and extended bedtimes. (C) Mean ± SE sleep duration on the weekday nights (Sunday through Thursday) and the weekend nights (Friday and Saturday).

Table 2
Effect of bedtime extension on vigor and appetite ratings.[a]

Characteristic	Habitual bedtimes	Extended bedtimes	*P* value
Vigor ratings			
Sleepy	6.9 (0.9)	2.4 (0.8)	0.004
Global vigor	4.5 (0.8)	6.9 (0.6)	0.034
Appetite ratings			
Overall appetite	4.0 (0.6)	3.5 (0.6)	0.030
Sweet and salty foods (*cake, candy, cookies, ice cream, pastry, chips, salted nuts, pickles, and olives*)	2.4 (0.6)	0.9 (0.2)	0.017
Starchy food (*bread, pasta, cereal, and potatoes*)	5.1 (1.0)	4.1 (1.0)	0.156
Fruits and fruit juices	6.4 (1.1)	6.1 (1.1)	0.632
Vegetables	2.1 (1.1)	2.5 (1.0)	0.478
Meat, poultry, fish, and eggs	5.0 (1.1)	5.2 (0.9)	0.764
Dairy (*milk, cheese, and yogurt*)	4.8 (1.1)	4.5 (1.1)	0.785

Data are mean (SE).
[a] Average ratings on a visual analog scale from 0- to 10-cm.

overweight young adults who habitually curtail their sleep. We report for the first time that additional sleep has beneficial effects on food desirability with decreased cravings for weight promoting sweet and salty foods in this at-risk population. These findings demonstrate the feasibility of sleep extension in real life settings, where individuals have other priorities competing with sleep, and suggest that obtaining adequate sleep might have beneficial effects on food desire in individuals who are at risk for obesity.

We have used a home-based intervention through counseling on sleep hygiene. Behavioral modifications that were recommended to extend bedtimes were individualized to meet each participant's needs and lifestyle. Based on participants' self-report at the end of the study, the restriction of electronic media exposure (i.e. television and internet use) too close to bedtime or when in bed before going to sleep, was a key behavioral component for the success of the intervention in all 10 participants. In agreement with our data, cross-sectional studies have shown that TV viewing and computer use is associated with delayed bedtimes and reduced sleep duration (Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2013; Nuutinen, Ray, & Roos, 2013). A recent study also suggests that promoting household routines, particularly increasing sleep duration and reducing TV viewing, may be an effective approach to reduce body mass index among preschool aged children (Haines et al., 2013).

Our finding that sleep extension (objectively measured) is feasible in real life settings is consistent with two recent reports where extending sleep duration (assessed by self-reported sleep diaries) had beneficial effects on neurocognitive function in habitually short sleeping healthy and obese individuals (Gumenyuk, Korzyukov, Roth, Bowyer, & Drake, 2013; Lucassen et al., 2014). On average, our participants obtained 1.6 h more sleep with extended bedtimes, which is comparable in magnitude to the difference in sleep duration reported in prior studies as having adverse effects of sleep restriction on diabetes and obesity risk (Darukhanavala et al., 2011; Nedeltcheva, Kessler, Imperial, & Penev, 2009; Nedeltcheva et al., 2009; Robertson, Russell-Jones, Umpleby, & Dijk, 2013). Thus, the amount of additional sleep obtained in real life settings could conceivably have important metabolic implications to reduce obesity and diabetes risk. Consistent with this hypothesis, a longitudinal study reported that a spontaneous shift in sleep duration from short to healthier amount (≤6 h to 7–8 h) was associated with attenuated fat gain over 6 years (Chaput, Despres, Bouchard, & Tremblay, 2012).

Our participants also reported being less sleepy and more vigorous when they obtained additional sleep, which could potentially lead to increased physical activity. Consistent with this hypothesis, we have found that our participants had increased daytime activity (based on wrist monitors) during the intervention period as compared with the baseline period. Indeed, observational data in free-living adults at risk for diabetes show that persons who habitually curtail their sleep have more sedentary behavior, where sleep loss related declines in physical activity strongly correlate with reductions in subjective vigor (Bromley, Booth, Kilkus, Imperial, & Penev, 2012).

We have found that additional sleep in the home environment was associated with decreased overall subjective appetite and a 62% reduction in desire for sweet and salty foods. Erstwhile desire for fruits, vegetables and protein-rich nutrients was not affected by added sleep. These findings suggest that added sleep may help individuals to make healthier food choices as recommended by the USDA guidelines on the MyPlate designation (USDA's MyPlate, 2011). Our data are consistent with anecdotal reports of less cravings for sweet and salty snacks in obese adults who extended their habitual sleep duration (Cizza et al., 2010) as well as with the findings from previous short-term laboratory studies in healthy volunteers, in which sleep restriction was associated with increased appetite ratings, particularly more cravings for calorie-dense foods high in fat and sugar (Greer et al., 2013; Schmid et al., 2008; Spiegel et al., 2004) and increased consumption of carbohydrates from snacks (Nedeltcheva et al., 2009). A recent laboratory study involving brain imaging in sleep deprived healthy young volunteers has identified alterations in specific brain regions that may be involved in increased desire for high-calorie foods, and thus provides a potential biological mechanism by which sleep restriction may lead to poor food choices (Greer et al., 2013). Indeed, multiple neural systems and pathways are involved in appetitive drive and food intake (Berthoud, 2012; Berthoud, Munzberg, Richards, & Morrison, 2012). Of interest, future mechanistic studies could investigate how sleep extension affects the lateral hypothalamic orexin neurons, which are known to play a key role in the interactions between sleeping and feeding behaviors (Sakurai, 2005). Our finding that sleep extension is associated with reduced desire for high calorie foods is in agreement with a laboratory study in healthy volunteers showing that transitioning from an insufficient to adequate/recovery sleep decreased energy intake, especially of fats and carbohydrates (Markwald et al., 2013).

Our study has several limitations. This was a single center study with a small sample size in overweight individuals with selective eligibility criteria, which may limit the generalizability to more diverse populations. The exclusion of sleep disorders was based on self-report and not a laboratory sleep study. Extended bedtimes were implemented over a short period of 2-weeks, and thus the study does not provide information on the potential effects of an intervention sustained over a longer period (e.g. months to years). Nevertheless, at the end of the study, we asked the participants to complete a brief survey inquiring how easy or difficult it was to implement sleep extension in their daily life and whether they are likely to continue extending their bedtimes in the long-term. Seven out of 10 participants found the intervention fairly easy and nine out of 10 participants said that they are likely to continue to obtain more sleep in the long-term because they have noticed several beneficial effects (e.g. more energy, better mood, more alertness etc.). Another limitation is that we did not collect information on meal frequency and timing and assessed food desirability only in the morning hours before breakfast. Previous studies reported an increase in appetite and caloric intake in the morning (breakfast), and to a greater extent in the evening hours (Brondel, Romer, Nougues, Touyarou, & Davenne, 2010; Nedeltcheva et al., 2009; Spaeth, Dinges, & Goel, 2013). We thus predict that the effects on food desirability that were observed in this study after extended bedtimes would have been larger if measurements were repeated later during the day. We did not collect data on actual energy intake or assess the changes in appetite regulating hormones in this outpatient study, and thus the subjectivity of appetite measures that we report could be per-

ceived as a limitation. Yet, the only available method to objectively track energy intake in free-living individuals involves a combination of the measurements of total energy expenditure by doubly labeled water method with quantification of changes in body energy stores. We believe that such rigorous studies in free-living environment would be the next logical step toward addressing the question as to whether changes in appetite following sleep extension would result in behavioral changes in food consumption. Finally, we have chosen a study design where participants served as their own control beginning with habitual bedtimes followed by extended bedtimes. Importantly, participants were blinded to the behavioral recommendations until the beginning of the intervention period. Our finding with regard to the positive shifts in attitude toward longer sleep times and the participants' desire to continue this behavior after the 2-week intervention period suggest that future research efforts may not be able to use a randomized order of sleep interventions in outpatient studies. After experiencing the positive effects of extending sleep to the healthy range, it is unlikely that these behavioral changes will "washout" prior to a control period. Nevertheless, it is important to note that our study did not include a randomized design with a separate control arm (e.g. randomized controlled parallel group design), and thus we cannot necessarily exclude additional environmental factors (not assessed in our study) that may have contributed to our findings.

In summary, a 2-week home-based intervention to extend bedtimes can successfully increase sleep duration in real life conditions and obtaining adequate sleep increases vigor and decreases cravings for weight promoting sweet and salty foods in overweight young adults who habitually curtail their sleep. These findings have important implications for current efforts to reduce the burden of obesity and diabetes. Future intervention studies of longer duration with robust assessments of energy balance and metabolism under free-living conditions are warranted to investigate whether obtaining adequate sleep, which could be implemented in clinical scenarios, is an effective strategy to reduce metabolic risk and to improve the success of adherence to lifestyle regimens for the prevention and treatment of obesity and diabetes. The demonstration of a clear benefit of additional sleep on energy metabolism in real life settings would provide a strong incentive to adopt healthy sleep habits in individuals who are overweight or obese, and may benefit millions of Americans.

Statements

Authors Esra Tasali, Florian Chapotot, Kristen Wroblewski and Dale Schoeller declare that they have no conflict of interest relevant to this article.

The funding sources had no role in the study design or concept; the collection, management, analysis, or interpretation of the data; or the preparation, review, or approval of the manuscript.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consents were obtained from all participants for being included in the study.

This work described in this article has not been published previously and is not under consideration for publication elsewhere and its publication is approved by all authors.

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